

AREA DISPLAYS OF THE ELECTRICAL ACTIVITY OF THE HEART

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Abstract

Routine methods of studying electrical activity of the heart by means of curves recorded from various points on the precordium and extremities have contributed much to our knowledge of electrocardiography. Nevertheless, it has been very difficult to visualize movements of electrical activity across the surface of the heart by using the curves obtained in routine fashion. A new method of visualizing these phenomena has been developed and is presented in this paper.

* This work was completed June 30, 1949.

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AREA DISPLAYS OF THE ELECTRICAL ACTIVITY OF THE HEART

I. Area Display

The present paper describes a new method, called electronic mapping or area display, for obtaining information about the electrical activity of the heart. This method gives motion pictures of the movement of electric potentials in the heart, as projected on the surface of the chest. These pictures make available a great deal of apparently new information about the electrical activity of the heart, which when properly interpreted should be of value in studying the physiology of the heart and in the diagnosis of heart disease.

In the method of area display of chest potentials, a picture of the electrical potential distribution on the surface of the chest is shown on the screen of a cathode ray tube. A diagram of the method is shown in Fig. 1. A number of electrodes are placed in an

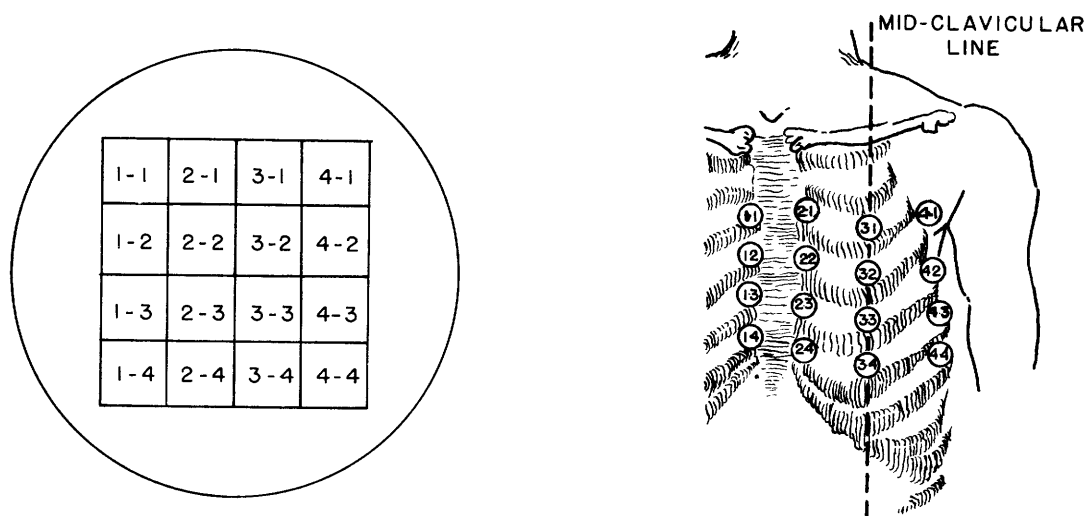


Fig. 1 Locations of electrodes on the chest and corresponding locations of areas on the cathode ray tube screen.

ordered array on the chest. Corresponding to each electrode is a small square on the screen of the cathode ray tube, each square being identified in Fig. 1 by the same number as its corresponding electrode. With the aid of electronic means described elsewhere (1) the light intensity of each square on the screen is made proportional to the instantaneous voltage of the corresponding electrode on the chest. As the potential at an electrode rises and falls, the brightness of the corresponding square rises and falls in exact synchronism with it.

If all of the chest were electrically neutral (isoelectric), all the squares on the cathode ray tube would be of a dull medium intensity. If positive potentials appeared at any electrodes, the corresponding squares would be bright* and the relative brightness

* The frame prints in Figs. 5 and 7 are photographic negatives, and show the roles of brightness and darkness reversed from the present description.

would be proportional to the corresponding positive potential. If negative potentials appeared at any electrodes, the corresponding squares would be dark and the relative degree of darkness would be proportional to the magnitude of the corresponding negative potential. In this way, if a wave of positivity crosses the chest, a wave of brightness crosses the cathode ray tube screen. If a wave of negativity crosses the chest, a wave of darkness crosses the screen. More generally, if a wave of electrical activity crosses the chest, a wave of activity can be seen to cross the screen, picturing the path of the electrical activity.

It is obvious that the potentials used in the method of area display are the same as those studied in conventional electrocardiography. One might therefore be tempted to ask what information is given by the method of area display that is not given by more orthodox electrocardiography. One who has not seen the moving pictures of area display might conclude erroneously that this technique shows nothing not already known.

The value of the area display depends particularly upon two characteristics of visual perception (2). In the first place, the human visual perception mechanism has a remarkable ability for recognizing and analyzing area patterns. Thus, for example, family resemblances can be recognized between parents and children in cases where the details of the geometry of the face which are the basis for the recognition often cannot be analyzed or even described. It is also well to point out the importance of experience in such situations. For example, to a European who does not know any Chinese people well, all Chinese tend to look alike. Similarly, to a Chinese who does not know any Europeans well, all Europeans look quite alike. Nevertheless, both Europeans and Chinese easily recognize minute differences between people of their own race and especially between people of their own acquaintance. The second characteristic of the human visual perception mechanism which is useful in dealing with area displays is the ability to detect motion. The perception mechanism is able to ignore even a complicated stationary pattern and to discern within it that portion which is moving.

The foregoing two characteristics make it possible for an experienced operator to recognize in area display, patterns and motion which could be derived with difficulty, if at all, from orthodox tracings.

There are four possible conventions which could be used in the visual and electrical polarities of area displays. The system described above shows brightness on the screen for positive potentials and darkness for negative potentials. The background area of the screen outside the array is dark. Negative prints of this system will, of course, show brightness and darkness reversed. The foregoing possibilities give rise to convention I and II in Table 1. If the electrical polarities required for brightness and darkness on the cathode ray tube screen are reversed, we will then have conventions III and IV. It is not entirely a matter of indifference which convention is used in practice. The acuity of the human visual perception system in dealing with various types of activity will depend on the convention used. The final choice to be made for general use will

depend upon what electrical and visual conventions turn out to be best. It is too early to recommend a choice at this time.

Table I

Possible Conventions Regarding Visual and Electrical
Polarities in Area Displays

Convention specification number	Electrical polarity for whiteness on film	Color of background	Type of photographic print
I	Positive	Black	Positive
II	Negative	White	Negative
III	Negative	Black	Positive
IV	Positive	White	Negative

It is found that the electrical activity on the surface of the chest gives an informative picture of the conduction of electrical impulses within the heart itself. This was to be expected in the light of experience with conventional precordial electrocardiography. In most cases, however, the activity takes place so rapidly that the best results are obtained by taking moving pictures of the cathode ray tube screen and showing the pictures in slow motion. These pictures show the location and sequences or paths of activity of the P, QRS and T waves in normal individuals and in those having heart disease. By way of illustration, diagrams of the paths of activity observed in a few typical cases are shown in Fig. 2. The arrows in the figure indicate the direction of

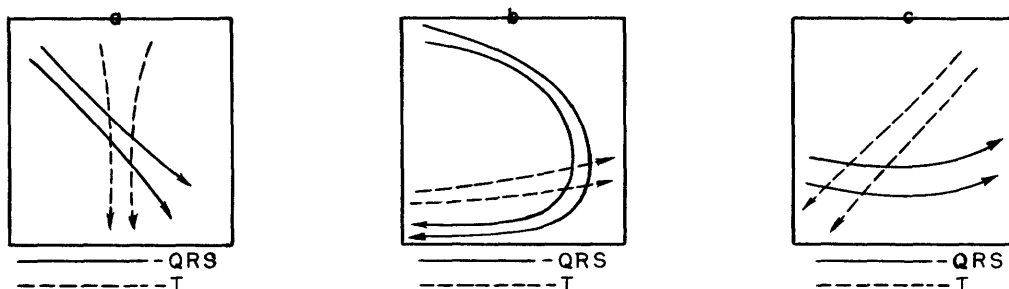


Fig. 2 Location and sequences or paths of activity of the QRS and T waves in typical cases: a) normal; b) right bundle-branch block; c) left ventricular hypertrophy.

motion of the activity. It is interesting to note that it is often difficult and sometimes impossible to synthesize the movements of the potentials across the chest from a study of sets of consecutive frames such as shown in Figs. 5 and 7, even though the eye sees these movements readily in the moving pictures.

Motion pictures of area displays are suitable for the purposes of obtaining permanent

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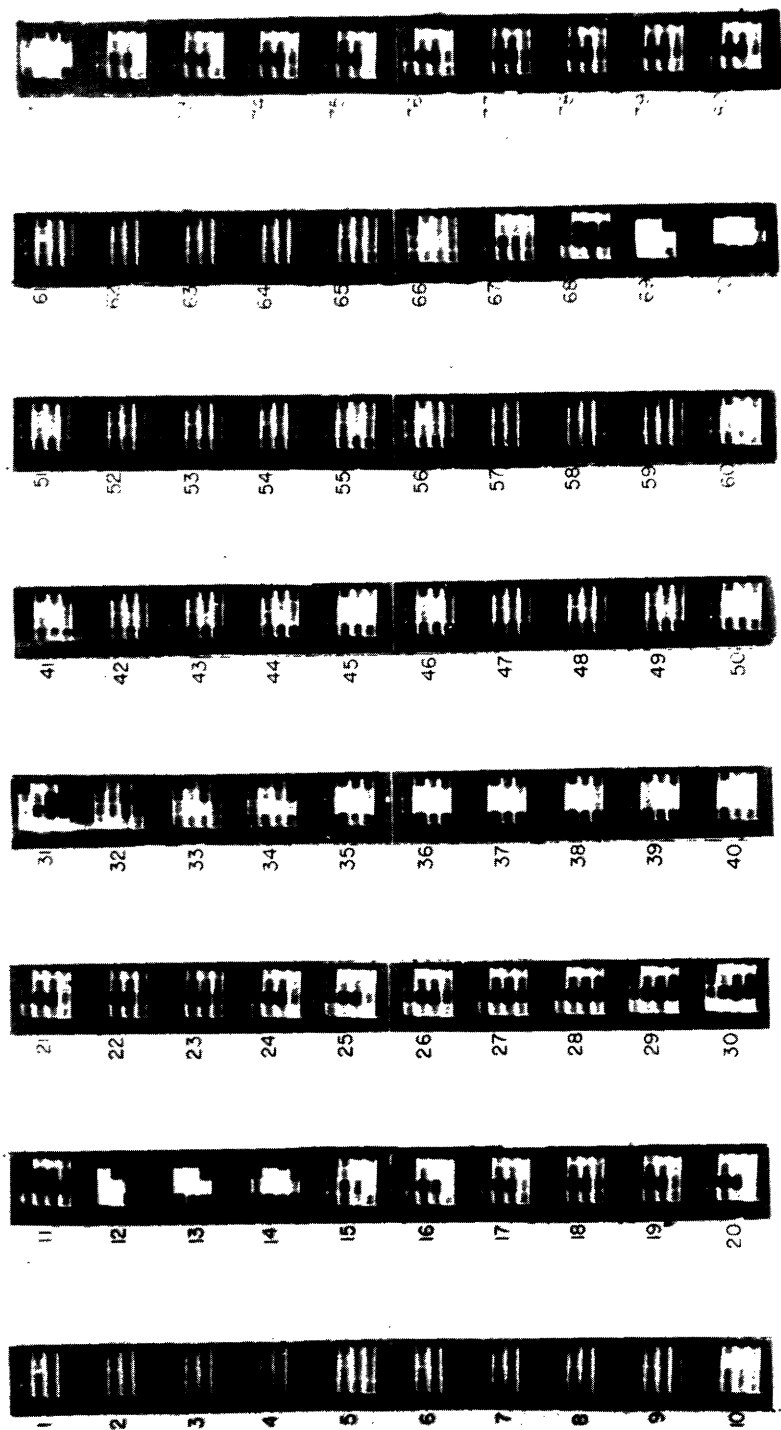


Fig. 5 Consecutive frame prints of a motion picture reel showing the area display of a normal subject.

The cover is usually necessary, however, in mapping skull potentials when studying the brain. The sides of the shielding screen box are fastened together with wing nuts and are readily removable.

The electrode wires are marked or color coded at both ends with the position they are to assume in the array. This avoids the necessity of tracing the wires each time and allows them to be laced into a bundle. Each lead wire has a banana plug at the end which leads to the amplifiers so that it can be plugged into a pickup box. The pickup box is located in an opening in one of the sides of the shielding enclosure. Between the pickup box and the amplifiers, the lead wires are surrounded with a grounded shield.

Each of the array terminals in the pickup box is connected through a resistance to a common reference terminal (see Fig. 4). With the circuits used, the potential of this reference terminal is approximately the average of the potentials appearing on the 16 array electrodes at that instant. The actual voltage which is sent through the amplifiers from any array terminal is the difference in potential between this terminal and the reference terminal. We also usually ground the subject's left arm to the shielding enclosure, which in turn is tied to the electrical ground of the amplifiers. This last procedure tends to reduce artifacts, and with suitable values for R and R_1 it should have very little effect on the physiological potentials sent to the amplifiers. We are studying the desirability of replacing the above reference terminal with a Wilson central terminal.

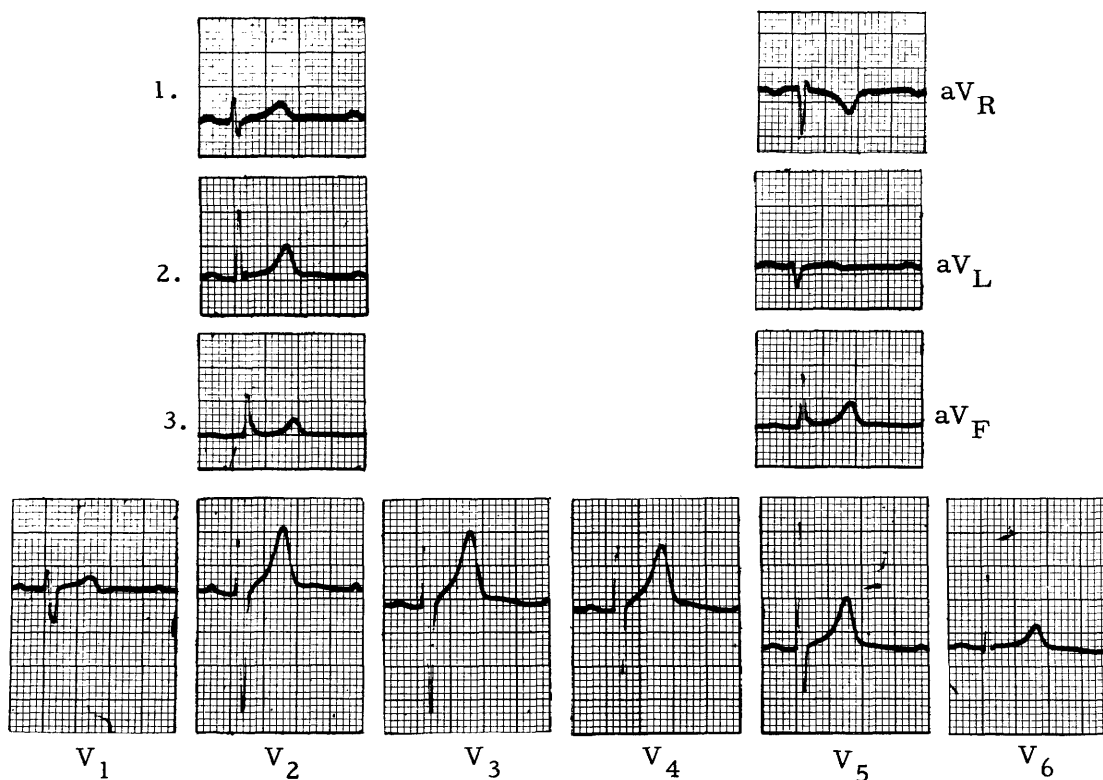


Fig. 6 Standard cardiogram of same subject as that of Fig. 5.

III. Discussion of Two Records

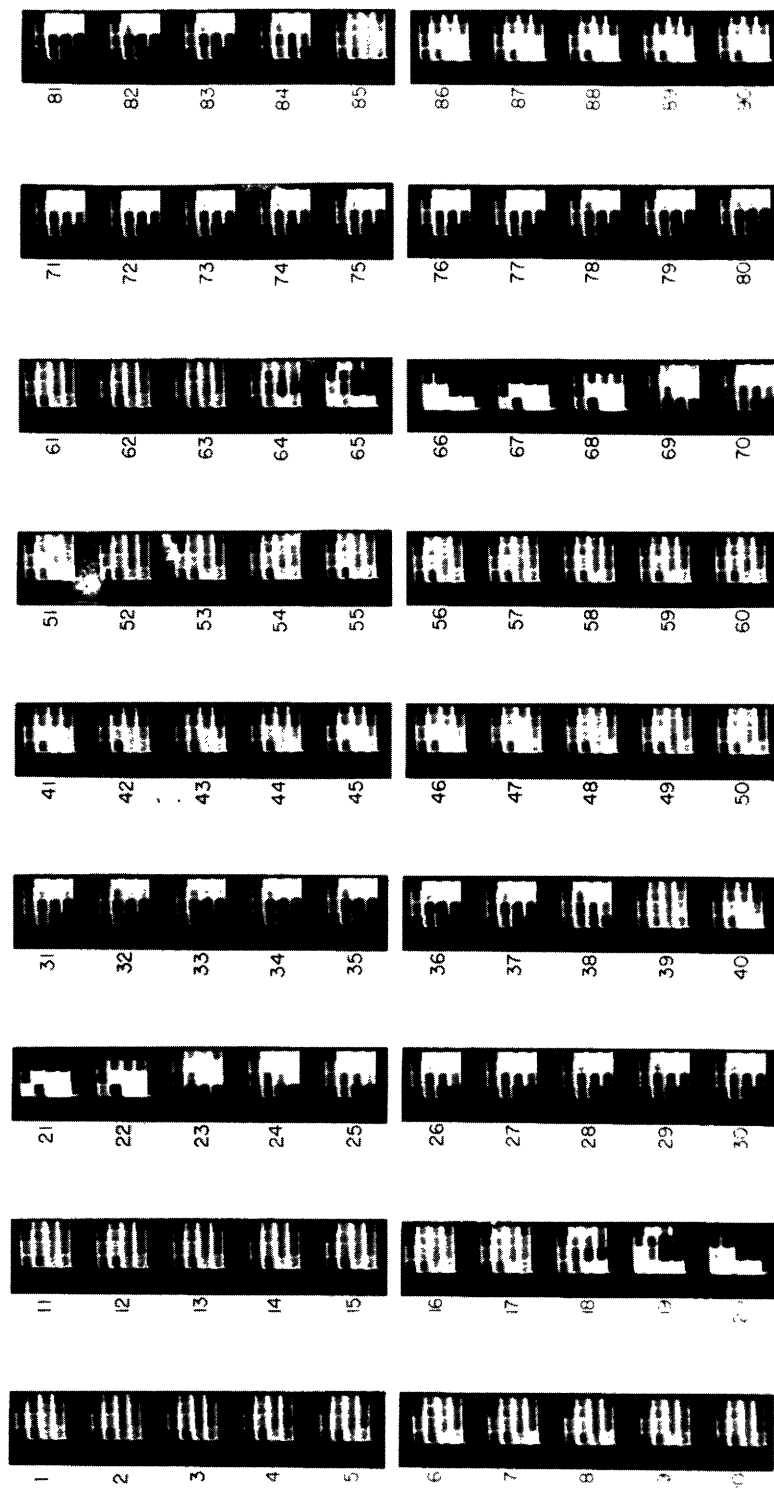
Figure 5 represents consecutive frame prints of the film taken on a normal young student. A standard electrocardiogram of the same subject is shown in Fig. 6. For purposes of comparison, it may be noted that frames numbered 3 through 5 represent the approximate duration of the P wave. Frames 10 through 16 represent the approximate duration of QRS. T activity appears to start around frame 16 and continues to somewhere in the vicinity of frame 34. The next P activity then occurs in the approximate range between 57 and 60 with QRS starting at 66. A detailed analysis of these frame prints will not be attempted at this time. It may be pointed out, however, that brightness on the frame prints represents electrical negativity while darkness represents electrical positivity. When the motion picture is viewed, rapid motion is observed during the QRS activity. The direction of the motion is shown in Fig. 2a. During the T interval, a slower motion of less intense activity may be observed in the direction indicated for T in the same figure. It should be emphasized that the directions of the arrows shown in Fig. 2 represent the direction of movement of activity as seen on the motion picture screen. They do not represent the directions of vectors of electrical force.

Figure 7 represents the prints of consecutive frames of a motion picture reel showing the area display of a subject having left ventricular hypertrophy. Figure 8 is a six lead electrocardiogram on this subject. Figure 7 includes a premature beat. In Fig. 7, frames 18 through 25 represent the approximate duration of the QRS of a normal beat. T activity of this beat ranges approximately from frame 24 through 38. QRS activity of the next beat is approximately from frame 64 through 71, and the corresponding T activity runs from frame 70 to about 84. In frames 100 to 106, the QRS activity of a premature beat is seen which is followed by T activity that appears to have an initial phase from frame 108 through 120 and a final phase from frame 121 through 135. Frames 155 through 161 show the QRS activity of the next regular beat and the corresponding T activity is seen in frame 161 through 176. In the case of this subject also, no detailed analysis of the frames will be attempted. The directions of motion observed in the moving picture for the regular beats of this subject are shown in Fig. 2c.

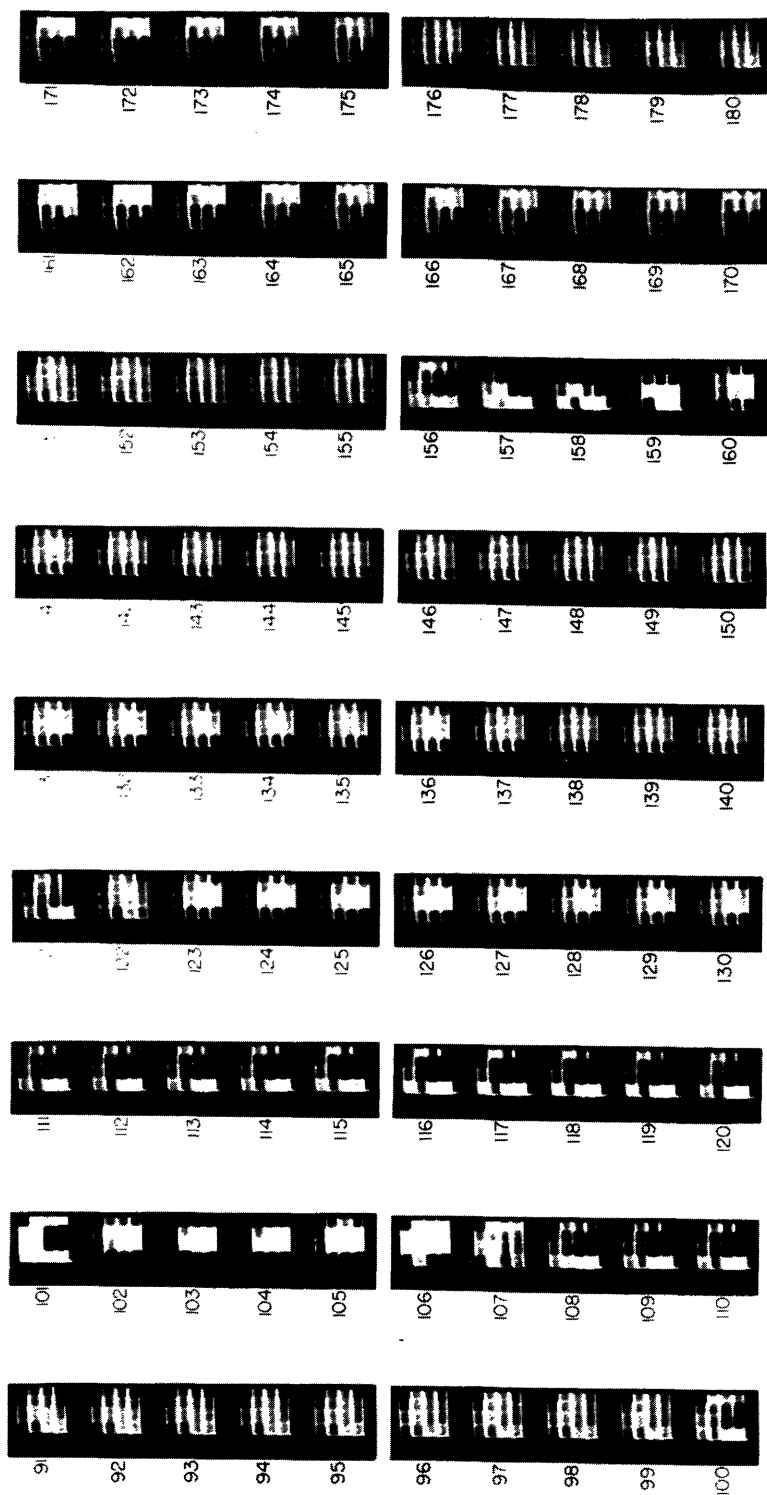
IV. Plans for the Future

The use of area displays in physiological studies is in its infancy. Many things which can and should be done in area display investigations are fairly obvious. For reasons of cost and size, we have so far used only equipment with sixteen pickup electrodes. It seems likely, however, that the electrical information on the surface of the chest has sufficient resolution to justify the use of at least as many as 200 electrodes. The technical obstacles which must first be overcome before the use of such a large number of electrodes is feasible are not fundamental, so that the use of larger numbers of electrodes may soon be expected.

Figs. 7 (a and b).



a



b

Fig. 7 Consecutive frames of a motion picture reel showing the area display of a subject having left ventricular hypertrophy.

Another obvious improvement is the use of larger slow-down ratios in the motion pictures. This is particularly important in studies of the QRS activity. Cameras have recently appeared on the market which make a ratio of as much as 200 to 1 possible. This is more than adequate for present studies.

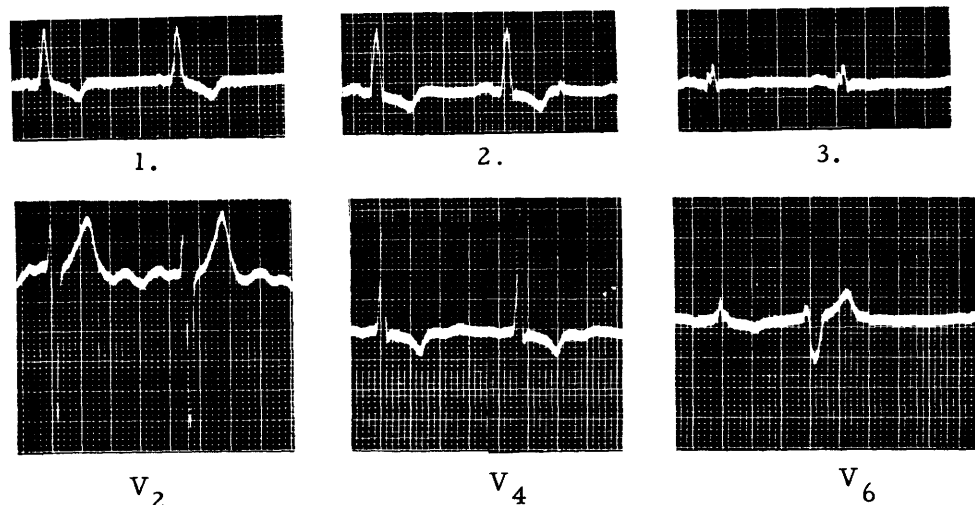


Fig. 8 Standard cardiogram of same subject as that of Fig. 7.

Early in this work, the necessity for synchronized registration of a standard tracing along with the area display became apparent. Apparatus which accomplishes this is now nearly completed.

As pointed out in the beginning of this paper, the motion pictures so far obtained give information only about the movement of electrical potentials in the heart as projected on the surface of the chest. It would, of course, be desirable to have more direct information about actual movement of electrical activity in the heart itself. We are planning to improve our interpretation in this respect in two ways as soon as possible. In the first place, we shall attempt to coordinate our motion pictures with vector cardiography in the same patients. In the second place, we intend to study area pictures taken with electrodes located directly on the hearts of experimental animals.

It is hoped that the application of this method will prove helpful in arriving at a better understanding of the T wave. It is also possible that abnormal patterns of area display will be recorded in patients with heart disease who show normal electrocardiograms by routine methods.

We are already accumulating the beginning of a library of motion picture reels of the area displays of normal and abnormal hearts. These will, of course, become obsolete as soon as equivalent reels taken with newer equipment are available.

We hope that other investigators will also start to use area displays. After more general experience has been gained, it will be desirable to standardize electrode locations and also to standardize terminology for the description of pictures.

Area displays will undoubtedly be used in other fields of physiology and diagnosis.

They have already begun to be used in studies of the brain (3) and attempts will be made to use them in studies of the bladder, in childbirth, and in studies of spastic and paralyzed muscles.

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